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MARTIN MARIETTA

ZIP – The ZIP-Code Insulation Program (Version 1.0) Economic Insulation Levels for New and Existing Houses by Three-Digit ZIP Code

Users Guide and Reference Manual

Stephen R. Petersen

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USERS GUIDE AND REFERENCE MANUAL

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NOTICE: This document contains information of a preliminary nature. It is subject to revision or correction and therefore does not represent a final report.

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PREFACE

The ZIP computer program was developed to support the calculations and data base used to estimate the economic levels of insulation published in the U.S. Department of Energy's *Insulation Fact Sheet* (DOE/CE-0180, Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831, 1987). This program allows individual users to estimate economic levels of insulation for their house, based on local climate data, local prices for energy and insulation, and the type and estimated efficiency of its heating and cooling system. While the current program is limited to calculating economic insulation levels for attic floors, exterior walls, floors over crawlspaces, and crawlspace and basement walls, it is anticipated that this will be expanded to include other components, such as windows, water heaters, and duct work in unconditioned spaces. Programmatic direction of this project and the DOE *Insulation Fact Sheet* has been provided by David McElroy of the Oak Ridge National Laboratory.

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ABSTRACT

ZIP 1.0 (the ZIP-Code Insulation Program) is a computer program developed to support the DOE *Insulation Fact Sheet* by providing users with customized estimates of economic levels of residential insulation. These estimates can be made for any location in the United States by entering the first three digits of its ZIP Code. The program and supporting files are contained on a single 5.25-in. diskette for use with microcomputers having an MS-DOS operating system capability. The ZIP program currently calculates economic levels of insulation for attic floors, exterior wood-frame and masonry walls, floors over unheated areas, slab floors, and basement and crawlspace wells. The economic analysis can be conducted for either new or existing houses. Climate parameters are contained in a file on the ZIP diskette and automatically retrieved when the program is run. Regional energy and insulation price data are also retrieved from the ZIP diskette, but these can be overridden to more closely correspond to local prices.

ZIP can be run for a single ZIP Code and specified heating and cooling system. It can also be run in a "batch" mode for any number of consecutive ZIP Codes in order to provide a table of economic insulation levels for use at the state or national level.

---

1. INTRODUCTION

1.1 OVERVIEW

ZIP 1.0, the ZIP Code-Insulation Program, determines economic levels of insulation for attics, exterior walls, floors over unheated areas, slab floors, and basement and crawlspace walls for new and existing houses in any three-digit ZIP Code location in the United States. The

R-value to the next is found to be cost effective, that increment will be included in the report of cost-effective insulation levels for that location. If it is not cost effective, that increment will not be included. In general, the colder the climate and the higher the cost of energy, the more it pays to add insulation and the higher the economic levels resulting from the analysis.

Economic calculations are based on a reduction in long-term heating and cooling costs. For new houses, a 30-year life is used in calculating the economic level of insulation. That is, the economic level of insulation calculated for a new house will be the level which has the lowest combined insulation cost plus energy cost over a 30-year period. For existing houses, a 20-year life is used in the calculations.

In performing these calculations, a minimum 7% annual rate of return, over and above general inflation, is used to discount future savings to present value. If inflation is currently 5%, this is approximately equivalent to requiring a minimum 12% rate of return on the investment. Each increment of insulation must earn at least this much "interest" to be considered cost effective. Residential energy savings are not taxed, so that this is in effect an after-tax rate of return on investment. Moreover, the first increments of added insulation typically return much higher dividends than the last increment. Thus the average rate of return tends to be considerably higher than the minimum acceptable level.

The results of the economic analysis for the designated location are displayed on the screen, as shown in screen 1.1 for a new house in ZIP Code 809XX (Colorado Springs). The reference location is typically the location designated by the U.S. Postal Service as the main post office for the three-digit ZIP Code. The number of annual heating degree days (base 65°F) and cooling degree hours over 74°F are shown for the designated location, along with the heating and cooling systems used in the analysis.

Screen 1.1 shows the screen display of economic levels for all of the components that can be evaluated by ZIP. In general, however, economic levels are displayed only for those components selected for analysis by the user for the particular application. Screen 1.2 shows additional information for floors over crawlspaces and crawlspace walls that can be displayed by pressing <PgDn>. To return to the ZIP analysis screen, press <PgUp>.

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Screen 1.1. Display of ZIP analysis for new house

```
              Economic Insulation Levels for Zip 809XX
              Reference Location: Colorado Springs, CO
 Heating system: HEAT PUMP                Cooling system: HEAT PUMP
--------------------------------------------------------------------------
                        New House Construction

            Attic Insulation                                R-38
            Wood-Frame Wall Insulation                      R-19
            Masonry Wall Insulation                         R-11
            Floors over Crawlspace
               (If crawlspace walls are uninsulated)        R-30
            Crawlspace Wall Insulation
               (If floor above is uninsulated)              R-19
            Slab-Edge Insulation                            R- 4
            Insulation of Basement Walls:
             Exterior Insulation for Deep Basement          R- 8
             Interior Insulation for Deep Basement          R-11
             Exterior Insulation for Shallow Basement       R- 8
             Interior Insulation for Shallow Basement       R-11

--------------------------------------------------------------------------
                Press <PgDn> for additional information.
           Press <SHIFT> <PrtSc> to print this screen if desired.
              Press <ESC> to exit, R to do another analysis:
```

Screen 1.2. Additional information with ZIP analysis

```
                        Additional information

     Insulate either the floor over the crawlspace or the crawlspace
     walls, not both.  Consult an insulation specialist to determine
     which is more appropriate for your house.

     Crawlspace walls should only be insulated if the crawlspace is
     closed off, unventilated, and dry all year.   The ground should
     be covered with a vapor barrier (e.g., 4- or 6-mil polyethylene
     sheeting) to minimize moisture migration into the crawlspace.
     Note: some building codes may not allow unventilated crawlspaces.
     If radon gas is a problem at the building site, closing off the
     crawlspace may not be advisable.

     When insulating floors over crawlspaces or other unheated areas,
     make sure that water pipes are freeze-protected and ductwork is
     well insulated in those areas.

--------------------------------------------------------------------------
           Press <SHIFT> <PrtSc> to print this screen if desired.
              Press <PgUp> to show economic insulation levels:
```

Note that the economic levels of insulation both under floors over crawlspace and on crawlspace walls are shown. However, only one of these would be used in most houses. For crawlspaces that do not need ventilation and can be closed off, it is usually more economical to insulate the walls than the floor if the wall area is less than the floor area. If the crawlspace cannot be safely closed off, the floor above should be insulated instead. In this latter case, care must be taken to insulate water pipes and any ductwork in the unheated area.

Energy savings and their estimated dollar value computed in the analyses are not shown in the screen display. These calculations are based on uniform surface areas for a typical house under average operating conditions for a typical year. They would not provide any meaningful estimate of savings for the user's house.

The insulation levels and corresponding costs in the insulation data file used by the ZIP program are the same for both new and existing houses, with the exception of the insulation for exterior wood-frame walls. In new houses, it is much less costly to insulate a wall before the inside surface is finished than it is to blow insulation into an existing wall cavity. Moreover, for a house under construction, thicker walls or insulated sheathing can be used to improve the its overall insulation effect, while in a completed house, the addition of insulation is generally limited to the available cavity in the existing wall.

Five different heating systems are recognized in the ZIP program: natural gas, oil furnaces, electric furnaces, electric baseboard, and electric heat pump. Two different cooling systems can also be handled: central and window electric air conditioners. (An evaporative cooling system can also be specified, but this is not treated as a true air-conditioning system.) In addition, the user can specify the approximate operating efficiency of the heating and cooling systems (low, medium, high, or very high).[1] These system specifications are needed to determine the energy savings corresponding to any given level of insulation. If there is ductwork in attics, crawlspaces, or other unheated areas, an adjustment is also made to the equipment efficiency in order to reflect duct losses.

---

[1]See Section 3 for specific assumptions regarding these efficiency designations.

1.2 ORGANIZATION

This user's guide provides the instructions needed to run the program and documentation of the calculation procedures and data files that are automatically accessed by the program. If you are anxious to get started, read Section 2, "Up and Running." This section will tell you how you can get the program running as quickly as possible, with a minimum amount of detail. Section 3 outlines the questions and appropriate user responses encountered while running ZIP. Section 4 describes the calculation procedures used in the program. Section 5 documents the data files that provide the climate data, energy prices, and insulation costs usethe program in calculating the economic levels.

2. UP AND RUNNING

ZIP will run on an IBM-PC/XT/AT or compatible MS-DOS microcomputer with approximately 256 K of random access memory (RAM). A printer is also useful -- but not necessary -- for making hard copies of the ZIP screen displays. With a printer, any screen display can be printed by holding down the <Shift> key and pressing <PrtSc> (or equivalent command).

The following files can be found on the original ZIP disk:

ZIP.EXE	The executable version of ZIP.
CLIMATE.DAT	A file of climate data, keyed to three-digit ZIP Codes.
INSCOST.NEW	A file of default insulation cost data for new houses.
INSCOST.RET	A file of default insulation cost data for existing houses.
ZIP.BAS	The source code version of ZIP.
ZIP.DOC	A short explanation of the ZIP program.

Files of default energy price projections for DOE regions 1 through 10:

ENPRICES.1	ENPRICES.4	ENPRICES.7
ENPRICES.2	ENPRICES.5	ENPRICES.8
ENPRICES.3	ENPRICES.6	ENPRICES.9
		ENPRICES.10

All of these files (except ZIP.BAS and ZIP.DOC) are needed to run ZIP. Copy these files to a new disk for running the program, and store the original disk in a safe place. There is no disk operating system (DOS) on the original ZIP disk. Thus, you should copy the files on this disk to a disk which has been formatted with DOS or to your fixed (hard) disk. If you are copying these files to a fixed disk, you might want to copy them to a subdirectory named ZIP.

To start the program, simply type ZIP at the ready prompt (e.g., A> **ZIP**) and press the carriage return <CR> (sometimes labeled as the <ENTER> key). All user entries must be completed by pressing <CR>. Screen 2.1 shows the initial message that will appear on the screen:

Screen 2.1. Initial ZIP screen

```
                     ZIP 1.0
          THE ZIP-CODE INSULATION PROGRAM
           FOR NEW AND EXISTING HOUSES
                   (Nov 1988)

  ZIP was written at the National Institute of Standards and Technology
  (formerly the National Bureau of Standards) to compute economic levels
  of insulation for attics, walls, floors, crawlspaces, and basements.

The economic level of insulation is the level that provides the greatest long-
term net savings to the homeowner, including a minimum rate of return of 7%
above inflation. (20 years used for existing houses, 30 years for new houses).

  Calculations of energy savings in ZIP are keyed to 3-digit Zip Codes.
   To start ZIP, please enter your Zip Code (first 3 digits only): ___
                    (Enter X to exit program)
```

Enter the first three digits of the ZIP Code for the location to be analyzed. For example, someone living in ZIP Code area 333 (Florida) would enter 333. The following message will appear on the screen:

Screen 2.2. Location confirmation

```
The reference location for Zip 333 in the Zip Climate File is:

                    Fort Lauderdale, FL

     Heating degree days (base 65F) are less than 1000
                         (very low)

   Cooling degree hours above 74F are approximately 34000
                     (extremely high)


       Press <CR> to proceed, or enter new ZIP Code:
```

The CLIMATE.DAT file on the ZIP disk has a reference location and relevant climate data for every three-digit ZIP Code in the United States. ZIP displays the reference location and climate data corresponding to the ZIP Code entered by the user. These climate data are generally representative of the entire three-digit ZIP Code. In some cases where there is a wide variation in climate within a single three-digit ZIP Code, as in the case of Zip 860 (Flagstaff, AZ), a message will appear with suggested ZIP Code alternatives, depending on locations within the ZIP Code. If the user is satisfied with this information, pressing <CR> will move on to the next question. Alternatively, another ZIP Code can be entered at this point and the corresponding location and climate data will be displayed. An "X" entered instead of a ZIP Code will terminate the analysis.

A number of questions will follow in order to make the economic analysis more responsive to the user's requirements. These questions and appropriate user responses are outlined in Section 3. However, it is not necessary to read Section 3 to answer the questions. Entering an "S" in response to any question will stop the current analysis and start the program over. Entering a "B" will back up one or more questions, allowing the user to change an earlier response.

3. ZIP QUESTIONS AND RESPONSES

A number of questions and user responses are needed to guide the ZIP analysis for particular applications. The user must specify an analysis for a new house or existing house and the type and approximate efficiency of the heating and cooling equipment in the house, as well as the current cost of heating and cooling energy. Questions are then asked about the components of the house that might need insulating and the current installed price of insulation, at several R-value levels, for each component. Default values are provided for all prices. If the analysis is to be performed for an existing house, several questions are asked about any insulation that might already be in place.

3.1 HEATING AND COOLING SYSTEMS

The following questions will be asked, unless they are not needed for the analysis. Each should be answered with a Y for yes or N for no, or when specified, a number corresponding to the choices given. Entering an "S" in response to any question will stop the current analysis and start the program over. Entering a "B" will back up to the previous question. Always press <CR> to complete any entry.

Screen 3.1. House type

```
DO YOU WANT INSULATION ANALYSIS FOR
         (1) NEW HOUSE
         (2) EXISTING HOUSE

Enter your selection by number:
```

Screen 3.2. Heating system type

```
WHAT TYPE OF PRIMARY HEATING SYSTEM DO YOU HAVE?

1) NATURAL GAS     (3) ELECTRIC FURNACE     (5) HEAT PUMP
2) FUEL OIL        (4) ELECTRIC BASEBOARD

Enter your selection by number (1-5):
```

For natural gas, fuel oil, and heat pumps:

Screen 3.3. Heating system efficiency

```
WHAT IS THE APPROXIMATE EFFICIENCY OF YOUR HEATING SYSTEM?
    (1) LOW    (2) MEDIUM    (3) HIGH    (4) VERY HIGH



            Enter your selection by number (1-4)
            or press <CR> to default to medium:
```

The following values are assigned to the four designated efficiency levels:

	Low	Medium	High	Very High
Efficiency: Gas	50%	65%	80%	90%
Oil	50%	65%	80%	90%
HSPF: Heat Pump[2]	5.5	6.5	7.5	8.5

The existence of ductwork in unheated areas is queried for all but electric baseboard heating systems. If such ductwork exists, the efficiency of the heating system is reduced (see Section 4) and the number of stories is requested, since the duct adjustment factor depends on this factor.

[2]Heating Seasonal Performance Factor, in Btu per watt-hour, at approximately 5000 heating degree days (base 65°F). The HSPF actually used is adjusted from the value shown to reflect local heating degree days, as documented in Section 4 of this user's guide.

Screen 3.4. Ductwork specification

```
DO YOU HAVE DUCTWORK IN ATTIC, CRAWLSPACE, OR OTHER UNHEATED AREAS (Y/N)?

                  DOES HOUSE HAVE 2 OR MORE STORIES (Y/N)?
```

If the primary heating system is not a heat pump, the type of air conditioning system is requested:

Screen 3.5. Air conditioning system

```
           WHAT TYPE OF AIR CONDITIONING SYSTEM DO YOU HAVE?

      (0) NONE                        (2) WINDOW UNIT-ELECTRIC
      (1) CENTRAL-ELECTRIC            (3) EVAPORATIVE COOLER

               Enter your selection by number (0-3):
```

For central and window units only, the efficiency of the air conditioner is requested:

Screen 3.6. Efficiency of air conditioner

```
      WHAT IS THE APPROXIMATE EFFICIENCY OF YOUR COOLING SYSTEM?
           (1) LOW     (2) MEDIUM     (3) HIGH     (4) VERY HIGH

   SEER[3]     6             8            10              12

              Enter your selection by number (1-4)
              or press <CR> to default to medium:
```

[3] Seasonal Energy Efficiency Ratio, in Btu per watt-hour. The SEER is not adjusted for local climate conditions since this tends to be relatively constant throughout the United States.

3.2 ENERGY PRICES

Current prices are now requested for heating energy and (if different) electricity for cooling. Default prices, retrieved from the ENPRICES file corresponding to the DOE region in which the ZIP Code is located, are shown first, e.g.:

Screen 3.7. Current energy prices

```
CURRENT NATURAL GAS PRICE FOR SPACE HEATING = $0.573
CURRENT ELECTRICITY PRICE FOR SPACE COOLING = $0.084

DO YOU WANT TO CHANGE THESE ENERGY PRICES TO BETTER
        REFLECT LOCAL PRICES (Y/N)?

Note: summer and winter electricity rates are different in many areas.
If they are different in your area, the rates shown above should be changed
to reflect this. (Use summer rates for cooling, winter rates for heating.)
```

These default prices are Department of Energy (DOE) estimates of current residential energy prices for the designated energy type and DOE region. (DOE regions include a number of states, so that the prices shown are not necessarily reflective of the ZIP Code location.) It is recommended that the user enter the current energy price at the building location for the type of energy used, in the units shown (therms[4] for natural gas, gallons for fuel oil, kWh for electricity). Where possible, prices should reflect the cost of the last unit purchased in the peak winter and summer months, not the average price. To change these default prices, enter Y; otherwise enter N.

If the energy prices are to be changed, the new price(s) to be used will be requested; e.g.:

---

[4] One therm = 100,000 Btu, or approximately 100 ft^3 of natural gas.

Screen 3.8. Change energy prices

```
ENTER CURRENT NATURAL GAS PRICE FOR HEATING ($/THERM)
            OR PRESS <CR> IF NO CHANGE:


ENTER CURRENT ELECTRICITY PRICE FOR COOLING ($/KWH)
            OR PRESS <CR> IF NO CHANGE:
```

The user should enter the new prices here. Note that the prices are entered in dollars, not cents (e.g., 8 cents is entered as 0.08, not 8; dollars signs should not be entered).

3.3 COMPONENT SPECIFICATION

The components of both new and existing houses that can be evaluated with ZIP are displayed in check-off form as shown on screen 3.9. The user should enter an X in each box corresponding to the insulation locations of interest. The up and down arrows on the keyboard can be used to move the cursor. An X in any box can be deleted by moving the cursor to that location and pressing the delete key or the space bar. Press <END> when this form is completed.

Screen 3.9. Insulation locations analyzed by ZIP

```
 MARK INSULATION LOCATIONS OF INTEREST WITH AN X
(Use cursor to move up and down, <End> to finish)

ATTIC                                       [ ]
Exterior walls:
  WOOD FRAME                                [ ]
  CONCRETE-MASONRY                          [ ]
Floors/crawlspaces:
  FLOORS OVER UNHEATED/UNINSULATED SPACES   [ ]
  SLAB FLOOR                                [ ]
  CRAWL SPACE WALLS                         [ ]
Basement walls - deep:
  EXTERIOR INSULATION                       [ ]
  INTERIOR INSULATION                       [ ]
Basement walls - shallow:
  EXTERIOR INSULATION                       [ ]
  INTERIOR INSULATION                       [ ]

          PRESS <End> WHEN FINISHED
```

While all of the checked locations can be evaluated by ZIP, it should be recognized that some of these insulation installations are mutually exclusive. That is, insulation would not be installed in both the floor over a crawlspace and on the crawlspace walls. Likewise, insulation would not be installed on both the inside and outside surface of basement walls. Where mutually exclusive locations are evaluated and reported, the user should generally select the more practical alternative for the particular house to be insulated.

For new houses, it is assumed that there is no existing insulation in any component. For existing houses, however, ZIP will ask a number of questions pertaining to the existing level of insulation in each component specified for analysis. If there is already existing insulation in the exterior walls, basement walls, or slab floor, no further analysis is performed, as further insulation is assumed to be impractical and uneconomic. If the user would still like to find the economic level for one of these components, ZIP should be rerun and questions regarding existing insulation for these components should be answered in the negative.

The following screens (3.10-3.19) are used for assessing the current insulation status for each of the checked components:

Screen 3.10. Existing attic insulation

```
                    Attic Insulation:

         HOW MUCH INSULATION IS THERE IN YOUR ATTIC NOW?

                               APPROXIMATE EQUIVALENT IN INCHES
                               -------------------------------
                                   FIBERGLASS       CELLULOSIC
                               ------------------     BLOWN
                               BATT        BLOWN     ----------

    0) NO INSULATION            0           0           0
    1) R-7                     2.5       2.0 -3.0    2.0-3.0
    2) R-11                    3.5       3.75-5.0    3.0-3.5
    3) R-19                    6.0       6.5 -8.75   5.0-6.0
    4) R-22                    7.0       7.5 -10.0   6.0-7.0
    5) R-30                    9.0      10.25-13.75  8.0-9.5
    6) R-38                   12.0      13.75-18.25 10.3-12.0

            ENTER YOUR SELECTION BY NUMBER (0-6):
```

The approximate amount of existing insulation in the attic should be entered here. Note that this amount is entered by the code number (0-6) in the far left column, not by the actual amount of insulation.

ZIP asks if there is existing insulation in wood-frame walls. The amount of insulation is not asked. If there is already some insulation in existing wall cavities, no analysis is made.

Screen 3.11. Existing insulation in wood-frame walls

```
                    Exterior Wood-Frame Walls:

          Do your walls already contain some insulation (Y/N)?
```

If information has been requested on masonry walls of existing houses, ZIP advises that this is not typically practical unless the interior wall board is about to be replaced or an exterior coating is about to be installed, independent of the decision to insulate.

Screen 3.12. Insulation of existing masonry walls

```
                      Exterior Masonry Walls:

  Insulation of masonry walls in existing houses is typically impractical
unless you are about to install new wall board or an exterior wall covering.
     Do you still want to include insulation of masonry walls (Y/N)?
```

If the user responds with Y(es), the following message appears on the screen:

Screen 3.13. Masonry wall retrofit advisory

```
   The economic analysis of insulation of masonry walls will not include
  the cost of removing and replacing the wall covering unless these costs
    are specifically included in the insulation costs displayed below.

                        Press <CR> to continue...
```

If there is a floor over an unheated crawlspace, either the floor or (under certain circumstances) the crawlspace walls may be insulated to reduce heat losses. If there is insulation already existing, this may be increased. The level of existing insulation in such floors, if any, is requested in screen 3.14. The level of insulation on the crawlspace walls, if any, is requested in screen 3.15. If there is already some insulation under the floor or on the crawlspace walls, ZIP assumes that any additional insulation would be installed over the existing insulation and not in the uninsulated wall or floor.

Screen 3.14. Existing insulation in floor over crawlspace

```
                  Floors over Crawlspaces:

        How much insulation is under the floor now?

                   Approximate   Approximate
                     R-Value      Thickness
                                  (inches)
                 (0)   R-0           0
                 (1)   R-7           2.5
                 (2)   R-11          3.5
                 (3)   R-13          4.0
                 (4)   R-19          6.0

        Enter your selection by number (0-4):
```

Screen 3.15. Existing insulation on crawlspace walls

```
                       Crawlspace Walls:
      How much insulation is on the crawlspace walls now?

                Approximate   Approximate
                  R-Value      Thickness
                               (inches)
              (0)   R-0           0
              (1)   R-7           2.5
              (2)   R-11          3.5
              (3)   R-13          4.0
              (4)   R-19          6.0

          Enter your selection by number (0-4):
```

Screen 3.16. Existing insulation on slab edges

Concrete Slab Floors:
Do you already have perimeter insulation around the concrete slab of your house (Y/N)?

If the slab is already insulated, no further analysis is performed for this component.

Screen 3.17. Existing insulation in basement walls

Basement Wall Insulation:
Is there some existing insulation in the basement wall (Y/N)?

If basement walls already contain some insulation, no further analysis is performed for this component. If no insulation is present and exterior wall insulation for deep basements has been checked for analysis, the following advisory notice is provided on the screen:

Screen 3.18. Deep basement insulation advisory

Exterior Insulation for Deep Basements:
For existing houses with deep basements, exterior insulation is generally practical for only the top half of the wall.
Only the top half will be evaluated in this analysis.
Press <CR> to continue...

If interior insulation for basement walls has been checked for analysis, the following question is asked:

Screen 3.19. Interior insulation on basement walls

```
Basement Walls (Interior Insulation):

Are the basement walls already finished off (Y/N)?
```

If the interior basement walls are already finished off, insulation on the inside is not evaluated. ZIP suggests that exterior insulation be considered. If the user still wants an economic analysis for insulation on the inside surface (for example, during remodeling when the wallboard is about to be replaced), this question should be answered negatively.

3.4 INSULATION COSTS

Default insulation prices are displayed for each level of insulation in each part of the house that is to be evaluated in the ZIP analysis. These levels and corresponding cost data are retrieved from the INSCOST.NEW or INSCOST.RET files. The former is for new houses; the latter is for existing houses. Adjustment factors corresponding to the designated location are used to reflect regional variations in the costs of insulation. (See "Insulation Price Files" in Section 5 for the adjustment factors used.) For attic insulation, the screen display will typically appear as:

Screen 3.20. Default insulation prices

```
The following prices will be used to compute economic levels of insulation
for your house unless you change them:

Attic Insulation Costs:
Note: costs are per square foot of gross attic area

R-11   $0.29 per square foot
R-19   $0.41 per square foot
R-22   $0.47 per square foot
R-30   $0.59 per square foot
R-38   $0.74 per square foot
R-49   $0.91 per square foot

Do you want to change these (Y/N)?
```

If these are to be changed to better reflect the installed insulation cost at the house, the user should respond with a Y(es). The user will then be able to change the cost for each level, or default to the current value shown. When changing these costs, the cost of any given level must always be greater than the cost of the previous level (e.g., the cost of R-38 must always be higher than the cost of R-30). (The levels that are shown can be changed only by changing the insulation data in the INSCOST files. See Section 4.)

Similar screens with cost data for the other components to be evaluated are displayed, and the cost data must be accepted or modified to local conditions.

3.5 RESULTS OF ZIP ANALYSIS

After accepting or changing these insulation prices, the results of the analysis will be displayed on the screen. Screen 1.1 in Section 1 shows the results for a new house. Screen 3.21 below shows the results for an existing house at the same location. Note that the same screen of additional information shown in screen 1.2 can be displayed for the analysis of an existing house.

Screen 3.21. ZIP analysis for existing house

```
                Economic Insulation Levels for Zip 809XX
                Reference Location: Colorado Springs, CO
 Heating system: HEAT PUMP                 Cooling system: HEAT PUMP
-------------------------------------------------------------------------
                        Retrofit of Existing House

                                            EXISTING     ADD      TOTAL
 Attic Insulation                             R-11       R-30      R-41
 Wood-Frame Wall Insulation                   R- 0       R-11      R-11
 Masonry Wall Insulation                      R- 0       R-11      R-11
 Floors over Crawlspace
    (If crawlspace walls are uninsulated)     R- 0       R-19      R-19
 Crawlspace Wall Insulation
    (If floor above is uninsulated)           R- 0       R-19      R-19
 Slab-Edge Insulation                         R- 0       R- 4      R- 4
 Insulation of Basement Walls:
  Exterior Insulation for Deep Basement       R- 0       R- 8      R- 8
  Interior Insulation for Deep Basement       R- 0       R-11      R-11
  Exterior Insulation for Shallow Basement    R- 0       R- 8      R- 8
  Interior Insulation for Shallow Basement    R- 0       R-11      R-11

-------------------------------------------------------------------------
                Press <PgDn> for additional information.
          Press <SHIFT> <PrtSc> to print this screen if desired.
               Press <ESC> to exit, R to do another analysis:
```

4. ZIP CALCULATION METHOD

This section documents the calculation of both energy savings and economic analyses used to determine the economic levels of insulation in ZIP. Reductions in space heating and cooling requirements and corresponding energy savings are always calculated in millions of Btu's per year, per square foot or linear foot, as appropriate.

4.1 REDUCTIONS IN ANNUAL SPACE HEATING AND COOLING REQUIREMENTS

4.1.1 Attics and exterior walls

The reductions in annual heating requirements (AHR) and annual cooling requirements (ACR) due to insulation in attics and in wood-frame and masonry walls are estimated using equations derived from the Lawrence Berkeley Laboratory PEAR[5] program in support of the proposed *ASHRAE 90.2P Standard for the Energy Efficient Design of New Low-Rise Residential Buildings*.[6] For these components, AHR and ACR are estimated in terms of Btu per square foot of component area. These equations are as follows:

$$\Delta ARH = HSLOPE \times HDD65 \times \Delta U/1000000$$
$$\Delta ACR = CSLOPE \times CDH74 \times \Delta U/1000000$$

where HSLOPE = 25.91 for attics, 21.19 for wood-frame walls, and 20.02 for masonry walls;
CSLOPE = 1.978 for attics, 1.005 for wood-frame walls, and 0.739 for masonry walls;
HDD65 = heating degree days base 65°F;
CDH74 = cooling degree hours base 74°F;
ΔU = reduction in the U-value of the attic or wall due to the increase in insulation level.

---

[5]Lawrence Berkeley Laboratory, *PEAR .1: Program for Energy Analysis of Residences*, Berkeley, California, 1987.

[6]American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., *Standard 90.2P: Energy Efficient Design of New Low-Rise Residential Buildings*, Atlanta, Georgia, 1987.

4.1.2 Floors, basement, and crawlspace walls

The reduction in AHR and ACR for floors over unheated spaces, slab floors, and crawlspace and basement walls are estimated using equations and parameters derived from J. Christian and W. Strzepek, "Procedure for Determining the Optimum Foundation Insulation Levels for New, Low-Rise Residential Buildings" (*ASHRAE Transactions*, 1987).[7] Reductions in space heating and cooling requirements per HDD65 and CDH74 were estimated in that report at several insulation R-values for floors over unheated areas (Btu/ft^2) and for slab floors, crawlspace walls, and exterior and interior insulation of both shallow and deep basement walls (all in Btu/lin ft). Values for other insulation R-values are computed in ZIP by interpolation (assuming that reductions in thermal loss or gain are proportional to the inverse of the overall thermal resistance of the component). For each of the components, the following equations are used to estimate reductions in AHR and ACR:

$$\Delta ARH = BETA_h \times HDD65/1000000$$

$$\Delta ACR = BETA_c \times CDH74/1000000$$

where $BETA_h$ = the reduction in AHR per HDD65 for a designated increase in component R-value,
$BETA_c$ = the corresponding reduction in ACR per CDH74.

The coefficients used in the analysis of these components (as reported by Christian and Strzepek) are listed in Appendix C.

4.2 EQUIPMENT EFFICIENCY

The seasonal energy efficiency of the heating and cooling equipment is designated as follows:

---

[7]The analysis described in the Christian-Strzepek report served as the basis of the insulation analysis used in the development of the *ASHRAE 90.2P Standard for the Energy Efficient Design of New Low-Rise Residential Buildings*.

	Low	Medium	High	Very High
gas furnace	0.50	0.65	0.80	0.90
oil furnace	0.50	0.65	0.80	0.90
heat pump				
HSPF (heating)	5.5	6.5	7.5	8.5
SEER (cooling)	7.25	8.75	10.25	11.75
air conditioner	6.0	8.0	10.0	12.0

electric furnace = 1.0
electric baseboard = 1.0

The HSPF of a heat pump varies significantly with climate and is adjusted in ZIP as a function of HDD65. The following equation was used to compute the adjusted HSPF for the medium efficiency heat pump[8]:

$$HSPF = 1.06 \times 3.412 \times [2.3 - 0.1(HDD65/1000)]$$

The coefficient 1.06 forces the adjusted HSPF to 6.5 Btu/Wh at 5000 HDD, the HSPF assigned to the medium efficiency system in the table above. For the low, high, and very high efficiency systems, the HSPF at any climatic location is scaled up or down proportionately.

4.3 DUCT LOSSES

All system efficiencies for houses with ductwork in attics and other unconditioned spaces are adjusted for duct losses by multiplying the efficiency (or HSPF/SEER) by the following coefficients:

1-story houses: 0.85

2-story or more: 0.90

Source: State of California Energy Commission, "Algorithms and Assumptions: HVAC Ducts," draft procedural manual for energy standards development (May 19, 1987).

---

[8]Blake, P. J., and Gernert, W. C., *Load and Use Characteristics of Electric Head Pumps in Single-Family Residences*, EA-793, Volume 1, Westinghouse Electric Corp., 1978.

4.4 ENERGY SAVINGS

Energy savings for gas- and oil-fired heating equipment (in millions of Btu's per year) are calculated from the reduction in annual heating requirements by dividing that reduction by the annual efficiency of the corresponding equipment, e.g.:

$$\text{energy savings (gas or oil)} = \Delta\text{AHR}/\text{seasonal efficiency}$$

Energy savings for heat pumps and air conditioners (in millions of Btu's per year) are calculated from the reductions in annual heating and/or cooling requirements by dividing these reductions by the product of HSPF × 3.412 or SEER × 3.412, as appropriate, e.g.:

$$\text{energy savings (electricity)} = \Delta\text{AHR}/(\text{HSPF} \times 3.412)$$

$$\text{energy savings (electricity)} = \Delta\text{ACR}/(\text{SEER} \times 3.412)$$

4.5 ECONOMIC CALCULATIONS

(a) $$\text{Present-value savings} = (\Delta\text{AHR})\ (\$/\text{unit}_h)\ (\text{unit}_h/\text{million Btu})\ (\text{UPW}^*_h) + (\Delta\text{ACR})\ (\$/\text{unit}_c)\ (\text{unit}_c/\text{million Btu})\ (\text{UPW}^*_c)$$

where $\$/\text{unit}_h$ = the current cost per unit of energy used for heating (e.g., \$0.08/kWh);

$\$/\text{unit}_c$ = the current cost per unit of energy used for cooling;

unit_h = the number of units of heating energy per million Btu (e.g., 10 therms = one million Btu);

unit_c = the number of units of cooling energy per million Btu (e.g., 293 kWh = one million Btu);

UPW^*_h = the modified uniform present worth factor for heating energy, given a study period, the discount rate, and the rate of heating energy price escalation over the study period;[9]

UPW^*_c = the modified uniform present worth factor for cooling energy, given a study period, the discount rate, and the rate of cooling energy price escalation over the study period.[9]

---

[9]Department of Energy long-term projections of the rate of increase in energy prices (by type and region) are retrieved from the ENPRICES file and used to calculate these UPW* factors for heating and cooling energy. For more information on this procedure, see Lippiatt and Ruegg, *Energy Prices and Discount Factors for Life-Cycle Cost Analysis*, NBSIR 85-3273-2 (Rev 6/87), National Institute of Standards and Technology, Gaithersburg, Maryland, 1987.

(b) Net savings = present value savings less the installed cost of insulation.

(c) Economic level = insulation R-value with the greatest net savings in the designated application.

5. SUPPORTING DATA FILES

5.1 THE CLIMATE DATA FILE

The climate data file (CLIMATE.DAT) is a random access file which contains location specific climate and regional identification data for all three-digit ZIP Codes. In random access files, data records can be retrieved by record number, rather than reading sequentially through the entire file to find the needed data. The record number used for the climate data file is the three-digit ZIP Code. The specific data in each record are (1) the reference location (city or town), (2) the state, (3) the building cost region, (4) the DOE region, (5) the heating degree days base 65°F (in thousands), and (6) the cooling degree hours over 74°F (in thousands). DOE and building cost regions are identified by state in Appendix A.

The random access file format is used for CLIMATE.DAT because of the fast retrieval speed for records and its compact method of storing data. However, this format makes it difficult to modify. In general, the data in this file are relatively permanent in nature and should not need to be changed by the user.

5.2 INSULATION PRICE FILES

There are two insulation price files, INSCOST.NEW for new houses and INSCOST.RET for existing houses. Insulation prices are entered in dollars per square foot of surface area or per linear foot of basement perimeter and should reflect the end cost to the user. National average prices should be used, as these are adjusted using regional adjustment factors in the ZIP program. These adjustment factors are shown in Table 1. The GNP deflator in the INSCOST files is used to adjust the insulation prices to current year dollars, allowing the use of older cost data in these files. If the insulation cost data is current, the GNP deflator should be 1.0.

Table 1. Regional insulation price adjustment factors[10]
(See Appendix A for corresponding locations)

Region	Factor	Region	Factor	Region	Factor
1	1.03	5	0.95	9	0.97
2	1.04	6	0.98	10	1.22
3	0.81	7	1.03	11	1.04
4	0.97	8	0.97	12	1.30

The data in both files are similar except for the wall insulation levels and prices. These files can be modified by the user using a text editor. However, the format and sequence of insulation types must be maintained. This format is shown in Table 2. The insulation price file for new construction, INSCOST.NEW, is shown in Table 3.

5.3 ENERGY PRICE FILES

There are ten energy price files on the ZIP disk (ENPRICES.1 -- ENPRICES.10), one for each of the ten DOE regions. These prices are long-term projections of residential energy prices in constant base-year dollars, as forecast by the Department of Energy's Energy Information Administration. These projections are published annually by the National Institute of Standards and Technology as NBSIR 85-32773, *Energy Prices and Discount Factors for Life-Cycle Cost Analysis*. The ten DOE regions and the states belonging to each are listed in Appendix A.

The format of the ENPRICES files is as follows:

```
comment                          'mandatory one line comment
year                             'base year for series
N                                'number of years in series
GNP deflator factor              'conversion factor from base year to
                                    current year dollars
E1...EN                          'electricity prices for N years
O1...ON                          'fuel oil prices for N years
L1...LN                          'LPG prices for N years
G1...GN                          'natural gas prices for N years
```

---

[10] Source: NAHB Research Foundation, *An Economic Data Base in Support of SPC 90.2: Costs of Residential Energy, Thermal Envelope, and HVAC Equipment*, Upper Marlboro, Maryland, December 1, 1986.

Table 2. Structure of insulation price file

```
comment                          'one line general file identification comment
                                         (note: comment must appear on first line)
GNP deflator factor              'to adjust these prices to current year
                                         dollars*
REGFACTOR(1)...REGFACTOR(12)'regional cost adjustment factors
                                         (see Table 1)
NCOMPS                           'NCOMPS = number of components with cost data in
                                         this file

For each component in this file
CAT                              'component index number (1-10)
                                          1 = attic
                                          2 = wood-frame wall
                                          3 = masonry wall
                                          4 = floor over crawlspace
                                          5 = crawlspace wall
                                          6 = slab-edge
                                          7 = deep basement, exterior
                                          8 = deep basement, interior
                                          9 = shallow basement, exterior
                                         10 = shallow basement, interior
CAT$(CAT)                        'component name
NCAT(CAT)                        'number of insulation levels to be specified for
                                         this component
CODEAREA(CAT)                    '1 = square foot, 2 = linear foot (perimeter)
MODEL(CAT)                       '1 = PEAR coefficient model [see Section 4(1a)]
                                 '2 = Christian-Strzepek model [see Section 4(1b)]
COMMENT$(CAT)                    'A comment or note to be printed to the screen
                                         when the insulation costs for this
                                         component are displayed on the screen.
                                         (Note: enter a space if no comment.)
If MODEL = 1:
  BASEU(CAT)                     'Base U-value of component before insulation is
                                         added

  FOR K=1 to NCAT(CAT)
    ADDR(CAT,K)                  'R-value of insulation level K to Component CAT
    ULEVEL(CAT,K)                'Corresponding U-value of component
    COST(CAT,K)                  'Corresponding installed insulation cost

If MODEL = 2:
    FOR K=1 to NCAT(CAT)
    ADDR(CAT,K)                  'R-value of insulation level K to Component CAT
    COST(CAT,K)                  'Corresponding installed insulation cost
```

*Use 1.0 if the prices are entered in current year dollars.

Table 3. Current INSCOST.NEW file*

```
insulation costs for new houses in 1985 dollars
1.12
1.03,1.04,0.81,0.97,0.95,0.98,1.03,0.97,0.97,1.22,1.04,1.30
9
1,ATTIC, 6,1,1
note: costs are per square foot of gross attic area
0.2540
11,0.0688,0.27
19,0.0455,0.38
22,0.0400,0.43
30,0.0333,0.54
38,0.0241,0.68
49,0.0199,0.84
2,WOOD FRAME WALLS, 5,1,1
note: costs are per square foot of net wall area
0.3763
11,0.0988,0.36
13,0.0899,0.44
19,0.0652,0.64
23,0.0504,1.15
26,0.0433,1.39
3,MASONRY WALLS,7,1,1
note: costs are per square foot of net wall area
0.263
3.8,0.164,0.22
5.7,0.130,0.36
7.6,0.108,0.52
9.5,0.092,0.67
11.4,0.080,0.82
15.0,0.068,1.78
21.6,0.056,2.20
4,FLOOR OVER UNHEATED AREA,4,1,2
note: costs are per square foot of gross floor area
11,0.38
13,0.45
19,0.56
30,0.76
5,SLAB ON GRADE - 2 FT VERTICAL, 6,2,2
note: costs are per linear foot of slab edge
4,2.04
5,2.25
8,2.69
10,3.50
12,4.02
15,4.58
```

(Continued on next page)

Table 3. (continued)

```
6,CRAWL SPACE WALLS,4,2,2
note: costs are per linear foot of crawl space perimeter
11,1.77
13,2.01
19,2.37
30,3.14
7,DEEP BASEMENT WALLS - EXTERIOR INSULATION, 6,2,2
note: insulation extends to bottom of basement wall
4,6.20
5,7.01
8,8.77
10,10.87
12,12.71
15,14.55
8, BASEMENT WALLS- INTERIOR INSULATION,3,2,2
note: costs are per linear foot of interior wall perimeter
11,6.48
13,7.20
19,10.24
9, SHALLOW BASEMENT WALLS - EXTERIOR INSULATION,6,2,2
note: insulation extends to bottom of basement wall
4,10.07
5,10.88
8,12.64
10,14.74
12,16.58
15,18.42
```

*Source: For attics and exterior walls, cost data for insulation was derived from NAHB Research Foundation, *An Economic Data Base in Support of SPC 90.2: Cost of Residential Energy, Thermal Envelope and HVAC Equipment*, Upper Marlboro, Maryland, 1986. For the floors, crawlspace, and basement walls, cost data for insulation was taken from J. Christian and W. Strzepek, "Procedure for Determining the Optimum Foundation Insulation Levels for New, Low-Rise Residential Buildings," *ASHRAE Transactions*, Vol. 93, Part 1, 1987.

(Note: the cost of insulating interior basement walls is assumed to be the same for both deep and shallow basements. Thus there are no addition cost data for the latter component in this file.)

An example of the current ENPRICES.1 file is shown in Table 4. If the study period exceeds the last year for which energy prices are available in the ENPRICES files, the last price in the series is automatically used by the ZIP program for all subsequent years.

The GNP deflator allows the use of energy price projections in constant dollars for years other than the current year. The price projections are adjusted to the current year by factoring in the GNP deflator. If the price projections are in designated today's dollars, the GNP deflator should be set at 1.0.

Table 4. ENPRICES.1 file

```
Energy prices for DOE region 1 in 1985 dollars
1985
26
1.12
25.44  25.04  28.21  29.07  28.45  27.63  26.81  25.74  25.08  24.93  24.84
24.59  24.51  24.37  24.79  25.08  25.08  25.08  25.08  25.08  25.08  25.08
25.08  25.08  25.08  25.08
7.65   4.40   4.65   4.84   5.09   5.33   5.54   5.98   6.60   7.24   7.78
8.23   8.63   8.95   9.29   9.66   9.66   9.66   9.66   9.66   9.66   9.66
9.66   9.66   9.66   9.66
8.21   4.73   5.00   5.20   5.47   5.73   5.95   6.42   7.08   7.78   8.35
8.84   9.27   9.60   9.97  10.36  10.36  10.36  10.36  10.36  10.36  10.36
10.36  10.36  10.36  10.36
8.04   7.27   7.10   7.02   7.47   7.64   7.79   8.19   8.60   8.82   9.23
9.50   9.80  10.04  10.28  10.68  10.68  10.68  10.68  10.68  10.68  10.68
10.68  10.68  10.68  10.68
```

APPENDIX A. REGIONAL CODES

The CLIMATE.DAT file contains two regional codes in each three-digit ZIP Code record. The first identifies the DOE region needed to retrieve the appropriate DOE energy price projections. The second identifies the building cost region needed to identify the appropriate regional adjustment factor for insulation prices. These codes are currently assigned as follows:

DOE Regions

1 Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island
2 New York, New Jersey
3 Pennsylvania, Maryland, West Virginia, Virginia, District of Columbia, Delaware
4 Kentucky, Tennessee, North Carolina, South Carolina, Mississippi, Alabama, Georgia, Florida
5 Minnesota, Wisconsin, Michigan, Illinois, Indiana, Ohio
6 Texas, New Mexico, Oklahoma, Arkansas, Louisiana
7 Kansas, Missouri, Iowa, Nebraska
8 Montana, North Dakota, South Dakota, Wyoming, Utah, Colorado
9 California, Nevada, Arizona, Hawaii
10 Washington, Oregon, Idaho, Alaska

Building Cost Regions[1]

1 Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island
2 New York, New Jersey, Pennsylvania, Maryland, District of Columbia, Delaware
3 West Virginia, Virginia, North Carolina, South Carolina, Georgia
4 Florida
5 Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, Texas
6 Kansas, Nebraska, Missouri, Kentucky, Iowa
7 Michigan, Wisconsin, Ohio, Indiana, Illinois, Minnesota, North Dakota, South Dakota
8 Montana, Idaho, Wyoming, Colorado, Nevada, Utah
9 Arizona, New Mexico
10 California
11 Washington, Oregon
12 Alaska

---

[1] Source: NAHB Research Foundation, *An Economic Data Base in Support of SPC 90.2: Cost of Residential Energy, Thermal Envelope and HVAC Equipment*, Upper Marlboro, Maryland, 1986.

APPENDIX B. RUNNING ALL ZIP CODES IN BATCH MODE

ZIP can be run in the "batch" mode to compute economic levels of insulation for all ZIP Codes (or any consecutive series of ZIP Codes) in one run. Economic levels of insulation are determined for all five heating systems (gas, oil and electric furnaces, electric baseboard, and electric heat pumps), all with electric air conditioning in locations having more than 2000 cooling degree hours per year over 74°F. The user can specify the components to be evaluated using the same menu shown in screen 3.9. The results of this batch analysis are printed to a disk file named by the user. This file can be edited by word processor for inclusion into a larger report. An example of the batch file is shown in Fig. B.1 for ZIP Codes 010-013.

The batch version of ZIP is executed by entering ZIP /BAT at the ready prompt (e.g., A> ZIP /BAT). The first and last three-digit ZIP Codes to be evaluated are requested. In addition, the disk drive and filename of the output file used to save the results of this analysis must be entered. If you are saving these results to a floppy disk rather than a hard disk, you should use a clean, formatted disk for this purpose as this output file can be quite large.

The batch version of ZIP uses the default values for energy and insulation prices, i.e., the prices in the INSCOST.NEW or INSCOST.RET files, as modified by the regional cost adjustment factors in those files (see Section 5). The equipment efficiencies are always assumed to be medium. (See Section 3 for corresponding values.) No ducts in unconditioned spaces are assumed.

Fig. B.1. Output File for Batch Mode of ZIP

New construction insulation analysis for Zip Codes 010 to 013
03-23-1988 11:25:28

Heating System Types:
(1) NATURAL GAS FURNACE
(2) OIL FURNACE
(3) ELECTRIC FURNACE
(4) ELECTRIC BASEBOARD
(5) HEAT PUMP

DESIGNATED COMPONENTS FOR ANALYSIS:
(1) ATTIC
Exterior walls:
(2) WOOD FRAME
(3) CONCRETE-MASONRY
Floors/crawlspaces:
(4) FLOORS OVER UNHEATED/UNINSULATED SPACES
(5) SLAB FLOOR
(6) CRAWL SPACE WALLS
Basement walls - deep:
(7) EXTERIOR INSULATION
(8) INTERIOR INSULATION
Basement walls - shallow:
(9) EXTERIOR INSULATION
(10)INTERIOR INSULATION

Economic R-Values for Designated Components

ZIP CODE	HTG SYS	1	2	3	4	5	6	7	8	9	10
010	1	38	19	11	30	4	19	8	11	8	11
	2	38	19	11	30	4	19	8	11	8	11
	3	49	26	11	30	8	30	15	11	15	13
	4	49	26	11	30	8	30	15	11	15	13
	5	38	19	11	30	4	19	8	11	8	11
011	1	38	19	11	30	4	19	8	11	8	11
	2	38	19	11	30	4	19	8	11	8	11
	3	49	26	11	30	8	30	15	11	15	13
	4	49	26	11	30	8	30	15	11	15	13
	5	38	19	11	30	4	19	8	11	8	11
012	1	38	19	11	30	4	30	8	11	8	11
	2	38	19	11	30	4	19	8	11	8	11
	3	49	26	11	30	8	30	15	11	15	13
	4	49	26	11	30	8	30	15	11	15	13
	5	38	19	11	30	4	30	8	11	8	11
013	1	38	19	11	30	4	30	8	11	8	11
	2	38	19	11	30	4	19	8	11	8	11
	3	49	26	11	30	8	30	15	11	15	13
	4	49	26	11	30	8	30	15	11	15	13
	5	38	19	11	30	4	30	8	11	8	11

APPENDIX C. BETA COEFFICIENTS FOR FLOORS, BASEMENT, AND CRAWLSPACE WALLS*

R-value	$BETA_h$	$BETA_c$
PLASTIC FOAM ON UPPER HALF OF DEEP BASEMENT		
4	20.69	0.34
5	1.01	0.03
8	1.92	0.07
10	0.86	0.03
12	0.70	0.03
15	0.89	0.04
PLASTIC FOAM ON FULL HEIGHT OF DEEP BASEMENT		
4	28.57	0.45
5	1.43	0.02
8	2.75	0.03
10	1.25	0.01
12	1.03	0.01
15	1.32	0.02
PLASTIC FOAM ON FULL HEIGHT OF SHALLOW BASEMENT		
4	44.35	0.95
5	2.03	0.04
8	3.66	0.07
10	1.52	0.02
12	1.19	0.02
15	1.42	0.02
BATT INSULATION ON INSIDE OF DEEP BASEMENT WALL		
11	34.24	0.51
19	0.96	0.01
30	2.35	0.01
BATT INSULATION ON INSIDE OF SHALLOW BASEMENT WALL		
11	51.36	1.08
19	1.12	0.02
30	2.50	0.03

(Continued on next page)

*Source: J. Christian and W. Strzepek, "Procedure for Determining the Optimum Foundation Insulation Levels for New, Low-Rise Residential Buildings," *ASHRAE Transactions* 93(1), 1987.

R-value	$BETA_h$	$BETA_c$
SLAB ON GRADE - VERTICAL 2 FT		
4	2.79	0.23
5	0.15	0.01
8	0.31	0.01
10	0.15	0.00
12	0.13	0.00
15	0.17	0.00
FLOOR INSULATION		
11	1.7	.12
19	0.26	0
30	0.26	0
CONCRETE-MASONRY CRAWL SPACE WALLS - BATTS		
11	21.80	0.93
13	0.40	0.01
19	0.87	0.02

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